MarLIN

Marine Information Network

Information on the species and habitats around the coasts and sea of the British Isles

Infralittoral fluid mobile mud

MarLIN – Marine Life Information Network
Marine Evidence–based Sensitivity Assessment (MarESA) Review

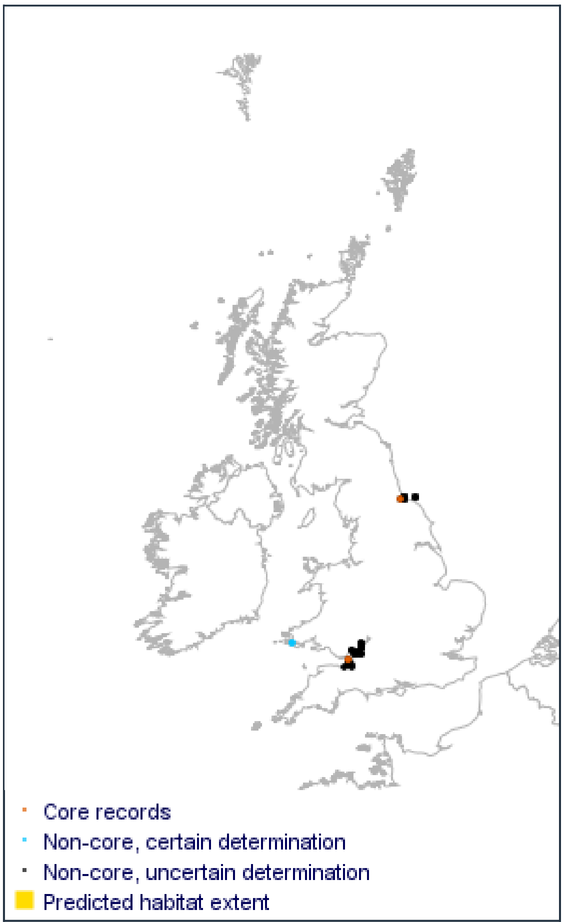
Dr Harvey Tyler-Walters

2018-11-23

A report from:
The Marine Life Information Network, Marine Biological Association of the United Kingdom.

Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [https://www.marlin.ac.uk/habitats/detail/55]. All terms and the MarESA methodology are outlined on the website (https://www.marlin.ac.uk)

This review can be cited as:
Tyler-Walters, H., 2018. Infralittoral fluid mobile mud. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. DOI https://dx.doi.org/10.17031/marlinhab.55.1



23-11-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Dr Harvey Tyler-Walters **Refereed by** This information is not refereed.

Summary

UK and Ireland classification

EUNIS 2008	A5.324	Infralittoral fluid mobile mud
JNCC 2015	SS.SMu.SMuVS.MoMu	Infralittoral fluid mobile mud
JNCC 2004	SS.SMu.SMuVS.MoMu	Infralittoral fluid mobile mud
1997 Biotope	SS.IMU.EstMu.MobMud	Infralittoral fluid mobile mud

Description

Fluid mobile mud suspended and deposited on each tide. In areas with very high quantities of suspended particulate material in the water column, it may become deposited around slack water when tidal currents fall. This can form fluid mud layers up to several metres thick (Warwick & Davis, 1977; Warwick & Uncles 1980) becoming a transient habitat in its own right. Species present within this biotope will be those washed in from other communities such as *Nephtys hombergii*, *Capitella capitata* or oligochaetes. This biotope may be under-recorded due to sampling problems and where sediment descriptions are absent from field data. It may be found adjacent to variable salinity mud biotopes SS.SMu.SMuVS.OlVS, SMu.SMuVS.NhomTubi, and SMu.SMuVS.CapTubi and to some extent SMu.SMuVS.AphTubi.(Information from Connor *et al*., 2004; JNCC, 2015).

Depth range

0-5 m, 5-10 m

Additional information

The Severn estuary is the 'type-location' worldwide for the mobile and stationary fluid muds exemplified by this habitat, although similar features have also been reported in the Humber estuary in the UK (Kirby & Parker, 1983; Kirby, 1997; Uncles *et al*., 2006; Kirby, 2010; Manning *et al*., 2010).

Listed By

- none -

Further information sources

Search on:

JNCC

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

Fluid muds are described from the Severn estuary and the Ouse estuary of the Humber estuary system in the UK (Warwick & Davies, 1977; Warwick & Uncles, 1980; Kirby & Parker, 1983; Kirby, 1997; Kirby 2010. The Severn is the 'type-location' for this feature and the physical processes that create 'fluid muds' (Kirby & Parker, 1983; Uncles *et al*., 2006; Kirby, 2010). Kirby & Parker (1983) describe mobile and stationary fluid mud features in the Severn estuary both of which can be described under this biotope.

Fluid muds (mobile and stationary) are physical features that form in extremely turbid conditions (high suspended sediment loads) in the turbidity maxima of the Severn and the Humber estuary systems in the UK and depend on the suspended sediment loads, the mass transport of water and sediment, and changes in tidal flow between low and high water of neap and spring tides (Kirby & Parker, 1983; Kirby 1997, 2010). Fluid muds take the form of mobile flows or 'lutoclines', mobile 'slugs' of sediment, or stationary pools of fluid mud at different phases of the tides. The 'pools' of stationary fluid muds are found preferentially in deep channels, e.g. Newport Deep and the Avonmouth area in the Severn (Kirby, 2010).

The fluid muds in the Severn are anaerobic and depaurate (Kirby, 1997, 2010). The fauna of the fluid muds is limited to those species mobilised from the sedimentary seabed and restricted to a few species in small numbers (Warwick & Davies, 1977; Connor *et al*., 2004). Therefore, the faunal component of the fluid muds is probably incidental and is not considered further in the sensitivity assessment. The sensitivity of this feature is determined by the physical factors that generate the fluid muds and any pressures that change those factors.

Resilience and recovery rates of habitat

Fluid muds (mobile and stationary) form in extremely turbid conditions (high suspended sediment loads) in the turbidity maxima of the Severn and the Humber estuary systems in the UK and depend on the suspended sediment loads, the mass transport of water and sediment, and changes in tidal flow between low and high water of neap and spring tides (Kirby & Parker, 1983; Kirby 1997, 2010). In the Severn, the estuary contains ca 30 Mt of sediment in suspension at high spring tides but ca 2 Mt two weeks later on low neap tides, the difference made up of extensive fluid mud pools in channels (Kirby, 2010). The sediment cycle is based on semi-diurnal and semi-lunar cycles of low and high spring and neap tides. Kirby (20101) suggested that the lutoclines, slug flow and fluid muds form above a threshold turbidity of 500 mg/l.

In the Severn, mobile fluid muds have suspended sediment concentrations of between <1 g/l and >150 g/l. They form as the tide decelerates but is still moving at ca 0.5-1 m/s. The suspended mud settles or dewaters through several stages or steps as the tide slows until, towards slack water, it forms a dense mobile layer of 3 - 150 g/l with a maximum thickness of ca 3 m. At slack water, these layers come to a halt and are stationary (Kirby & Parker, 1983). In the Severn, these fluid mud flows form 'slugs' of dense sediment, near to the bed moving under faster flowing surface waters, which then stagnate into the fluid mud pools recorded by echo sounders (Kirby, 2010). These pools form preferentially in deep channels e.g. in the Newport Deep and Avonmouth area (Kirby & Parker, 1983; Kirby, 2010). The stationary suspended sediment (fluid muds) have a concentration range of <0.1 to 200 g/l and a depth of ca 3 m in the Severn. They were generally 0.5-1.5 m deep in Newport Deep, reached only 0.5 m deep in Bridgewater Bay but reached 5 m deep in the channel from 'The Shoots' (Kirby & Parker, 1983).

In the Ouse, the near-bed suspended sediment layer in the tail region of turbidity maximum had characteristics of both mobile and stationary fluid muds (Uncles *et al.*, 2006). Uncles *et al.* (2006), recorded a fluid mud layer moving at 0.1-0.5 m/s with a suspended sediment concentration between 15-40 g/l and 0.5-3 m thick. The concentration increased to over 90 g/l at slack water as the fluid mud became stationary (Uncles *et al.*, 2006).

The fluid mud features are transient and short-lived. On spring tides the mobile fluid muds (lutoclines) retain their coherence for minutes to hours whereas on neap tides (lower mixing) they may remain for a few days at a time. As the neap tides return to springs, the stationary fluid mud pools are re-suspended (re-entrained) and mixed into the water body (Kirby, 2010). For example, near Avonmouth on tides with a height range of ca 7 m, stationary suspensions had a residence time of 3-4 days during neaps (Kirby & Parker, 1983). Kirby & Parker (1983) noted that a tidal range of ca 6.5 m at Avonmouth was an approximate limit below which detectable stationary fluid mud suspensions occurred throughout the estuary. These lower range tides occurred on up to 5 days (mean of 1.5 days) in the lunar cycle. Kirby (2010) noted that the largest amount of fluid muds on neap tides occurred after the equinoctial spring tides coincident with gales. However, fortnightly fluid mud increments were almost always re-eroded on the next spring tide (Kirby, 2010).

Resilience assessment. The mobile and stationary fluid muds are transient states dependent on the state of the tide (low and high water) and the lunar cycle (neaps and springs). They are formed, resuspended and reformed repeatedly throughout the tidal cycle and, although stationary fluid mud pools form in predictable and recorded positions within the estuary system, last for up to few days depending on location and state of the tidal cycle (Warwick & Uncles, 1980; Kirby & Parker, 1983; Kirby, 1997, 2010). Therefore, resilience is assessed as **'High'** except where a pressure has a long-lasting effect (after which recovery will be rapid) or is permanent.

Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence on the effect of temperature on the formation and retention of fluid mud features was found. Localised thermal effluents (see benchmark) may increase mixing of the water column as warmer or colder water rise or fall respectively. However, the main driver for the formation of the fluid mud features is tidal flow in highly turbid conditions. In addition, the mass transport of water in the large estuary systems in which these features form (e.g the Severn and Ouse) suggests that localised thermal plumes would be insignificant.

	Resistance	Resilience	Sensitivity
Temperature decrease (local)	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence on the effect of temperature on the formation and retention of fluid mud features was found. Localised thermal effluents (see benchmark) may increase mixing of the water column as warmer or colder water rise or fall respectively. However, the main driver for the formation of the fluid mud features is tidal flow in highly turbid conditions. In addition, the mass transport of water in the large estuary systems in which these features form (e.g the Severn and Ouse) suggests that localised thermal plumes would have an insignificant effect on the feature.

Salinity increase (local)	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Estuarine systems are transitional habitats between riverine freshwater and fully saline seawater. The position of the 'salt wedge' in the estuary, where low salinity water of riverine origin flows under higher saline seawater, varies with the time of year, rainfall, high and low water, neap or spring tides and the degree of mixing due to wind waves, storms or tidal flow. The transition between high and low salinity waters is associated with 'flocculation' and a resultant increase in turbidity. A change in salinity at the benchmark level (i.e. from full to reduced or reduced to low) occurs along the length of the estuary.

However, Kirby (2010) concluded that the main factor controlling the formation of fluid mud features was the semi-diurnal and semi-lunar tidal cycle. For example, he noted that heavy rain on exposed mudflats (and its associated localised decrease in salinity) perturbed the semi-diurnal and semi-lunar tidal mixing regime but was never large enough to disturb the cycle of the sediment behaviour observed (Kirby, 2010). In the Humber, the turbidity maximum occurred in the lower salinity reaches of the estuary but was displaced down the estuary by ca 12 km between spring and neap tides. Salinity was generally well mixed but large salinity inversions occurred in the presence of stationary suspended sediments (fluid muds) (ca 90 g/l). (Uncles *et al.*, 2006).

Sensitivity assessment. An increase in salinity to over 40 is only likely in areas subject to hypersaline effluents or brines. Roberts *et al.* (2010b) suggested that hypersaline effluent dispersed quickly but was a concern at the seabed and in areas of low energy where widespread alternations in the community of soft sediments were observed. Therefore, given the strong tidal streams, mass water transport and riverine input typical of the estuarine systems in which fluid mud features form, a hypersaline effluent is unlikely to have any significant effect. Therefore, resistance is assessed as **'High'** with 'Low' confidence. Therefore, resilience is probably **'High'** and sensitivity assessed as **'Not sensitive'** at the benchmark level.

Salinity decrease (local)	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Estuarine systems are transitional habitats between riverine freshwater and fully saline seawater. The position of the 'salt wedge' in the estuary, where low salinity water of riverine origin flows under higher saline seawater, varies with the time of year, rainfall, high and low water, neap or spring tides and the degree of mixing due to wind waves, storms or tidal flow. The transition between high and low salinity waters is associated with 'flocculation' and a resultant increase in turbidity. A change in salinity at the benchmark level (i.e. from full to reduced or reduced to low) occurs along the length of the estuary.

However, Kirby (2010) concluded that the main factor controlling the formation of fluid mud features was the semi-diurnal and semi-lunar tidal cycle. For example, he noted that heavy rain on exposed mudflats (and its associated localised decrease in salinity) perturbed the semi-diurnal and semi-lunar tidal mixing regime but was never large enough to disturb the cycle of the sediment behaviour observed (Kirby, 2010). In the Humber, the turbidity maximum occurred in the lower salinity reaches of the estuary but was displaced down the estuary by ca 12 km between spring and neap tides. Salinity was generally well mixed but large salinity inversions occurred in the presence of stationary suspended sediments (fluid muds) (ca 90 g/l). (Uncles *et al.*, 2006). Uncles *et al.* (2006) noted that salinity was insignificant to the dynamics of the estuarine turbidity maximum movement in the nose and upper core regions of highest suspended sediment concentrations.

Sensitivity assessment. Changes in the position of the 'salt wedge' may affect the position of the turbidity maxima in the estuary but given the highly turbid nature of the estuaries in which the fluid mud features are recorded, the effect is probably minimal. Therefore, resistance is assessed as **'High'** with 'Low' confidence. Therefore, resilience is probably **'High'** and sensitivity assessed as **'Not sensitive'** at the benchmark level.

Water flow (tidal current) changes (local)	Medium Q: Low A: NR C: NR	High Q: High A: High C: High	Low Q: Low A: Low C: Low

Kirby (2010) concluded that the main factor controlling the formation of fluid mud features was the semi-diurnal and semi-lunar tidal cycle, therefore, changes in the tidal regime and water flow may affect fluid mud features depending on their scale and magnitude. The Severn has a tidla range of 14.7 m, with a mean spring tidal range of 12.3 m and a mean neap range of 6.5 m that results in strong but variable tidal streams with a maximum spring flood of 2.3 m/s and a neap flood of 1.2 m/s at Avonmouth (Kirby & Parker, 1983; Kirby, 2010). Kirby & Parker (1983) noted that suspended sediment started to settle as the tide decelerated but while the suspension was still moving at 0.5-1 m/s and documented 'lutoclines' (mobile fluid muds) at ca 0.2 to 0.8 m/s near the seabed (Figure 8; Kirby & Parker, 1983; Kirby, 2010). In the Ouse / Humber estuary system, the highest concentration of suspended sediment in the fluid mud layer at 40 g/l moved at less than 0.1 m/s but was generally stationary at 90 g/l (Uncles *et al.*, 2006).

Sensitivity assessment. A change in peak mean spring bed flow velocity of between 0.1 m/s to 0.2 m/s for more than 1 year (the benchmark) over the entire estuary may alter the dynamics of fluid mud within the estuary. An increase may reduce their retention time while a decrease may increase their retention time. However, it is difficult to estimate the extent of the change as most mobile fluid muds form and move at speeds in excess of the benchmark. In addition, the system would probably return to prior conditions within a single tidal cycle once the pressure is removed (after one year). Therefore, resistance is given a precautionary assessment of **'Medium'** while resilience is probably **'High'** and sensitivity assessed as **'Low' at the benchmark level.**

However, obstacles in the water column or on the seabed may create larger effects at their locality depending on their size, position and duration. In particular, extensive permanent structures that affect the tidal regime are likely to adversely affect the fluid mud features. Kirby (1997; 2010) concluded that the Cardiff-Weston barrage proposal would result in loss of the physical processes that form the fluid mud features recorded in the Severn, and hence the features themselves, upstream of the barrage. Nevertheless, such a change is significantly greater than the benchmark and permanent.

Emergence regime changes	Medium Q: Low A: NR C: NR	High Q: High A: High C: High	Low Q: Low A: Low C: Low

The fluid mud features are subtidal but changes in emergence reflect changes in the tidal regime and the intertidal mudflats are an important source and sink for the suspended sediment in the estuarine system (see Kirby & Parker, 1983; Kirby, 2010). Kirby (2010) reported that the average sea level rise at Hinkley Point tide gauge was 4 mm/yr whereas the mean mudflat degradation rate at Stert Point was 16 mm/yr and cited CHaMP reported predictions of rapid intertidal habitat loss of 10-20% due to sea level rise in 100 years. Kirby (2010) estimated a foreshore erosion rate of ca 7 Mt/yr but also noted that Bridgewater Bay mud patch is both a sediment source and sink, while Newport Deep and is a long-term sink. Long-term changes in sea level are likely to submerge parts of the intertidal and affect currents within the estuary. Kirby (1997; 2010) also concluded that the construction of the proposed that the Cardiff-Weston barrage would result in loss of the physical processes that form the fluid mud features recorded in the Severn, and hence the features themselves, upstream of the barrage. Nevertheless, such a change is significantly greater than the benchmark and permanent.

Sensitivity assessment. An increase in sea level for ca 1 year (see benchmark) may result in loss of the intertidal area and may change the position of the salt wedge and turbidity maxima in the estuarine system. It may result in minor changes in the size, formation and retention rates of fluid mud features but recovery would be rapid once the system was returned to normal. Therefore, resistance is given a precautionary assessment of **'Medium'** while resilience is probably **'High'** and sensitivity assessed as **'Low' at the benchmark level.**

Wave exposure changes (local)	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Fluid mud features in the estuarine systems sheltered or extremely sheltered from wave action. However, Kirby (2010) reported that meteorological events such as wind waves perturb the semi-diurnal and semi-lunar mixing and settling of sediment responsible for the behaviour of fluid mud features in the Severn but were never large enough to destroy the observed cycle. Surface turbulence in the water column created by stormy days inhibited the process of suspended sediment settlement. But the largest amounts of fluid mud on neaps occurred after equinoctial spring tides that coincided with gales. Therefore, a 3-5% change in significant wave height (the benchmark) is unlikely to have a significant effect on the fluid mud features. Hence, resistance is assessed as **'High'**, resilience as **'High'** and the features are probably **'Not sensitive' at the benchmark level.**

Chemical Pressures

	Resistance	Resilience	Sensitivity
Transition elements & organo-metal contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **'Not assessed'**.

Hydrocarbon & PAH contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **'Not assessed'**.

Synthetic compound contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **'Not assessed'**.

Radionuclide contamination	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence

Introduction of other substances	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **'Not assessed'**.

De-oxygenation	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Kirby & Parker (1983) & Kirby (2010) note that fluid mud features are anaerobic, due to the presence of organic fines. The estuary bed and at times in summer the entire water body up-estuary of the Shoot Channel is deoxygenated by neap tide fluid mud or its resuspension in the neap-spring tidal cycle (Kirby, 2010). Therefore, the presence of fluid muds probably increases deoxygenation in their locality. However, the presence or absence of oxygen in the system probably has little or no effect on the physical fluid mud features, especially as the faunal component is also transient. Therefore, this pressure is 'Not relevant' to these features.

Nutrient enrichment	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Fluid muds and suspended sediment are involved in the transport of nutrients and organic material within the estuary system. The flocculation of organic material, especially as the saltwater-freshwater interface increases turbidity and probably contributes to the turbidity maxima. However, an increase or decrease in nutrients or organic enrichment is unlikely to make a significant difference in the physical processes that determine the cycling of mobile or stationary fluid muds features within the estuary system. Therefore, this pressure is probably **'Not relevant'**.

Organic enrichment	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Fluid muds and suspended sediment are involved in the transport of nutrients and organic material within the estuary system. The flocculation of organic material, especially as the saltwater-freshwater interface increases turbidity and probably contributes to the turbidity maxima. However, an increase or decrease in nutrients or organic enrichment is unlikely to make a significant difference in the physical processes that determine the cycling of mobile or stationary fluid muds features within the estuary system. Therefore, this pressure is probably **'Not relevant'**.

Physical Pressures

	Resistance	Resilience	Sensitivity
Physical loss (to land or freshwater habitat)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

Although unlikely in this instance, all marine habitats and benthic species are considered to have a resistance of **'None'** to this pressure and to be unable to recover from a permanent loss of habitat (resilience is '**Very low'**). Sensitivity within the direct spatial footprint of this pressure is, therefore '**High**'. Although no specific evidence is described confidence in this assessment is '**High**', due to the incontrovertible nature of this pressure.

Physical change (to another seabed type)	None Q: Low A: NR C: NR	Very Low Q: High A: High C: High	High Q: Low A: Low C: Low

Kirby (2010) suggests that the Severn estuary consists of a scoured seabed where most of the sediment is unconsolidated and mobile at any one place or time. The mobile and stationary fluid mud features consist entirely of fine sediments in various states of suspension and settlement. Although unlikely, if the sediment was replaced by hard or soft rock to fluid mud features would cease to exist. Therefore, resistance is assessed as '**None'** and resilience as '**Very low'** (as the change at the pressure benchmark is permanent). Hence, sensitivity is assessed as '**High'**.

Physical change (to another sediment type)	None Q: Low A: NR C: NR	Very Low Q: High A: High C: High	High Q: Low A: Low C: Low

The fluid mud features are composed of fine cohesive sediments or muds (Kirby, 2010; Manning *et al*., 2010). Although unlikely, a change from muds to sands or mixed coarse sediments would prevent their resuspension on the scale required to form the fluid muds features and probably result in the loss of the features. Therefore, resistance is assessed as '**None'** and resilience as '**Very low'** (as the change at the pressure benchmark is permanent). Hence, sensitivity is assessed as '**High'**.

Habitat structure changes - removal of substratum (extraction)	Low Q: Low A: NR C: NR	High Q: High A: High C: High	Low Q: Low A: Low C: Low

Removal of the substratum to a depth of 30 cm would result in loss of a portion the fluid mud in the footprint of the activity. Therefore, resistance is assessed as **'Low'.** However, the fluid mud would return and be replaced within days in the neap cycle or weeks in the spring cycle. Therefore, resilience is **'High'** and sensitivity is assessed as **'Low'**.

Abrasion/disturbance of the surface of the substratum or seabed	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Fluid mud features are by definition unconsolidated sediments in suspension. Any artificial structure or mechanism (e.g. trawl or dredge) passing through the suspension may result in very localised mixing of the suspension and disruption of the layering that results from the natural dewatering of the suspension. However, as the fluid muds are unconsolidated, and do not support a benthic community, little if any damage is envisaged. Therefore, resistance is assessed as **'High'.** Hence, resilience is **'High'** and the feature is probably **'Not sensitive'** to this pressure.

Penetration or disturbance of the substratum subsurface	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Fluid mud features are by definition unconsolidated sediments in suspension. Any artificial structure or mechanism (e.g. trawl or dredge) passing through the suspension may result in very localised mixing of the suspension and disruption of the layering that results from the natural dewatering of the suspension. However, as the fluid muds are unconsolidated, and do not support a benthic community, little if any damage is envisaged. Therefore, resistance is assessed as **'High'.** Hence, resilience is **'High'** and the feature is probably **'Not sensitive'** to this pressure.

Changes in suspended solids (water clarity)	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

This pressure addresses the increases in suspended sediment due to changes in sediment & organic particulate matter and chemical concentrations or activities disturbing sediment and/or organic particulate matter and mobilizing it into the water column. However, the suspended sediment concentrations typical of fluid mud features (ca 0.1 - 200 g/l) are significantly higher than the minimum value given for 'very turbid' conditions in the benchmark. Therefore, an increase in turbidity at the benchmark level is '**Not relevant'.** However, a decrease in suspended sediment could represent a major change in the fluid mud features. Although unlikely, any activity that significantly decreased the suspended sediment load within the estuary system could result in a reduction in the extent, duration and retention of the fluid mud features. But such a change in pressure is probably outside the scope of the definition and benchmark.

Smothering and siltation rate changes (light)	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Fluid mud features are composed of high concentrations of suspended sediments in various phases of settlement, flow and resuspension. In addition, the fluid mud features can vary in thickness from ca 0.5 m to up to 5 m (Kirby & Parker, 1983; Kirby, 2010). Therefore, the deposition of 5 or 30 cm of fine sediment is unlikely to have any noticeable effect. Therefore, resistance is assessed as **'High'.** Hence, resilience is **'High'** and the feature is probably **'Not sensitive'** to this pressure.

Smothering and siltation rate changes (heavy)	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Fluid mud features are composed of high concentrations of suspended sediments in various phases of settlement, flow and resuspension. In addition, the fluid mud features can vary in thickness from ca 0.5 m to up to 5 m (Kirby & Parker, 1983; Kirby, 2010). Therefore, the deposition of 5 or 30 cm of fine sediment is unlikely to have any noticeable effect. Therefore, resistance is assessed as **'High'.** Hence, resilience is **'High'** and the feature is probably **'Not sensitive'** to this pressure.

Litter	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

Not assessed.

Electromagnetic changes	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

This is a physical habitat with little or no faunal component. Therefore, this pressure is **Not relevant**.

Underwater noise changes	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

This is a physical habitat with little or no faunal component. Therefore, this pressure is **Not relevant.**

Introduction of light or shading	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

This is a physical habitat with little or no faunal component. In addition, the high turbidity prevents light penetrating into the water column. Therefore, this pressure is **Not relevant**.

Barrier to species movement	None Q: High A: High C: Medium	Very Low Q: High A: High C: High	High Q: High A: High C: Medium

This is a physical habitat with little or no faunal component. The definition of this pressure addresses the effect of obstructions to the movement of species rather than physical features. Technically, therefore this pressure is **Not relevant**. However, the construction of a tidal barrage in the Severn estuary has received considerable attention in the literature. Kirby (1997, 2010) concluded that the proposed Cardiff-Weston barrage would result in the loss of the physical processes that created the fluid mud features in the Severn estuary. Therefore, a precautionary resistance of **'None'** is recorded. In the case of a barrage, a permanent structure, recovery would not be possible and resilience is assessed as **'Very low'** and sensitivity as **'High'.**

Death or injury by collision	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

This is a physical habitat with little or no faunal component. Therefore, this pressure is **Not relevant**.

Visual disturbance	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

This is a physical habitat with little or no faunal component. Therefore, this pressure is **Not relevant**.

Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

This is a physical habitat with little or no faunal component. Therefore, this pressure is **Not relevant**.

	Resistance	Resilience	Sensitivity
Introduction or spread of invasive non-indigenous species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

This is a physical habitat with little or no faunal component. Kirby & Parker (1983) and Kirby (2010) argue that the unstable, transient and anaerobic nature of the fluid mud features mean that are largely uncolonized by species and depaurate. It follows that they are unlikely to be suitable for invasive non-indigenous species. Therefore, this pressure is **Not relevant**.

	Resistance	Resilience	Sensitivity
Introduction of microbial pathogens	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Kirby (2010) noted that contaminants and microbial pathogens can be carried by mobile fluid mud suspensions. But fluid muds are physical rather than biological features. Therefore, this pressure is **Not relevant**.

	Resistance	Resilience	Sensitivity
Removal of target species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

This is a physical habitat with little or no faunal component. Therefore, this pressure is **not relevant.**

	Resistance	Resilience	Sensitivity
Removal of non-target species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

This is a physical habitat with little or no faunal component. Therefore, this pressure is **Not relevant.**

Bibliography

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B., 2004. The Marine Habitat Classification for Britain and Ireland. Version 04.05. ISBN 1 861 07561 8. In JNCC (2015), *The Marine Habitat Classification for Britain and Ireland Version 15.03.* [2019-07-24]. Joint Nature Conservation Committee, Peterborough. Available from https://mhc.jncc.gov.uk/

JNCC, 2015. The Marine Habitat Classification for Britain and Ireland Version 15.03. (20/05/2015). Available from https://mhc.jncc.gov.uk/

JNCC, 2015. The Marine Habitat Classification for Britain and Ireland Version 15.03. (20/05/2015). Available from https://mhc.jncc.gov.uk/

Kirby, R. & Parker, W.R., 1983. Distribution and Behavior of Fine Sediment in the Severn Estuary and Inner Bristol Channel, U.K. *Canadian Journal of Fisheries and Aquatic Sciences*, **40** (S1), s83-s95. DOI 10.1139/f83-271

Kirby, R., 1988. High Concentration Suspension (Fluid Mud) Layers in Estuaries. In Dronkers, J. and van Leussen, W. *Physical Processes in Estuaries*, Springer Berlin Heidelberg, Berlin, Heidelberg, 1988, pp. 463-487.

Kirby, R., 1997. Environmental consequences of tidal power in a hypertidal muddy regime: the Severn estuary (UK). *La Houille Blanche*, (3), 50-56. DOI 10.1051/lhb/1997016

Kirby, R., 2010. Distribution, transport and exchanges of fine sediment, with tidal power implications: Severn Estuary, UK. *Marine Pollution Bulletin*, **61** (1), 21-36. DOI https://doi.org/10.1016/j.marpolbul.2009.12.011

Manning, A.J., Langston, W.J. & Jonas, P.J.C., 2010. A review of sediment dynamics in the Severn Estuary: Influence of flocculation. *Marine Pollution Bulletin*, **61** (1), 37-51. DOI https://doi.org/10.1016/j.marpolbul.2009.12.012

Roberts, D.A., Johnston, E.L. & Knott, N.A., 2010b. Impacts of desalination plant discharges on the marine environment: A critical review of published studies. *Water Research*, **44** (18), 5117-5128.

Uncles, R.J., Stephens, J.A. & Law, D.J., 2006. Turbidity maximum in the macrotidal, highly turbid Humber Estuary, UK: Flocs, fluid mud, stationary suspensions and tidal bores. *Estuarine, Coastal and Shelf Science*, **67** (1–2), 30-52. http://dx.doi.org/10.1016/j.ecss.2005.10.013

Warwick, R.M. & Davis, J.R., 1977. The distribution of sublittoral macrofauna communities in the Bristol Channel in relation to the substrate. *Estuarine and Coastal Marine Science*, **5**, 267-288.

Warwick, R.M. & Somerfield, P.J., 2010. The structure and functioning of the benthic macrofauna of the Bristol Channel and Severn Estuary, with predicted effects of a tidal barrage. *Marine Pollution Bulletin*, **61** (1), 92-99. DOI https://doi.org/10.1016/j.marpolbul.2009.12.016

Warwick, R.M. & Uncles, R.J., 1980. Distribution of benthic macrofauna associations in the Bristol Channel in relation to tidal stress. *Marine Biology Progress Series*, **3**, 97-103.